Release of Regulated Substances from UST Sites to Groundwater in Arizona:

The Final Report…

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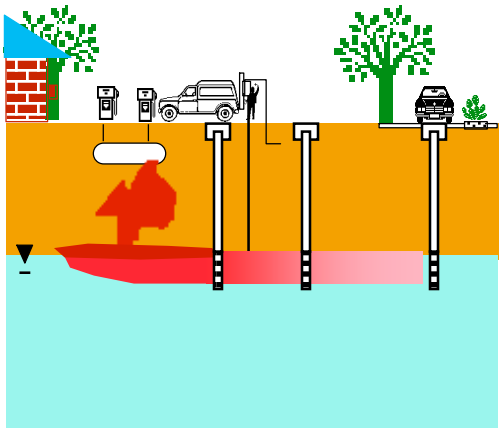


Disclaimer..

The results of this study reflect data collected from LUST sites over a wide time frame - they necessarily reflect changing practice, evolving guidance, and other external influences (e.g., reimbursement fund issues, etc.).

The observations are not to be taken as critiques of people, firms, or agencies involved in LUST-related work; rather they should be viewed as a reflection of "the system" - or the rules and practices associated with this work.

The observations should also be received in the spirit of continuous improvement and (hopefully) used to advance LUST programs and practice…

Much cooperation was received from ADEQ, Conoco-Phillips (Tosco?/Union 76?) and the consulting profession - Thank You!!!

Background - Vision *(back in 2001)…*

This study should provide information needed to answer the following basic questions:

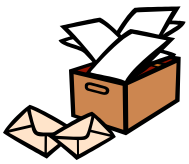
1. **For a given hydrogeologic setting and LUST release scenario - what type of groundwater impact is expected?**

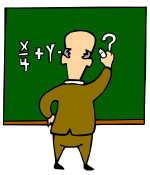
2. **What has been our experience with clean-up strategies in that setting (e.g., monitoring, clean-up, etc.)?**

Approach…

Answers to these questions will come from:

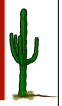
1. **A compilation and empirical analysis of existing data obtained from ADEQ file reviews.**
2. **Fundamental/theoretical considerations.**
3. **Supplemental data collection and analysis.**
4. **Lessons-learned from other related studies.**





Study Overview…

1. **A compilation and empirical analysis of existing data obtained from ADEQ file reviews.** — Approximately 12 months (and 400+ files)
2. **Fundamental/theoretical considerations.** — Spatial analysis of supply well - LUST site proximity and capture zone analysis…
3. **Supplemental data collection and analysis.**
   - Analysis of 700+ ground water samples
   - Assessment of Survey Errors (175 wells)
   - Assessment of Water Level Measurements
   - Slug tests at 11 sites
   - Dissolved plume "snapshots" at 6 - 8 sites
4. **Reviews by Expert Panel** — Bouwer, Huntley, and Rixey
5. **Final Report….** → 2/28/03 Issue Date



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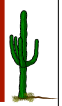
The Final Report: *Content*…

- Characterization of ADEQ LUST File Analysis Effort
- Characterization of LUST site characterization data (wells, sampling, etc.)
- Characterization of LUST sites
- Characterization of groundwater impacts at LUST sites
- Assessment of groundwater elevation measurements
- Supplemental aquifer characterization tests
- The six plume "snapshots" [before and after supplemental sampling]
- Relative locations of LUSTs and supply wells
- The attempt to assess the performance of remediation technologies…



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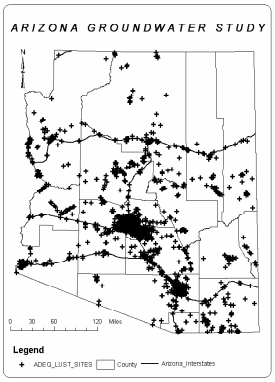
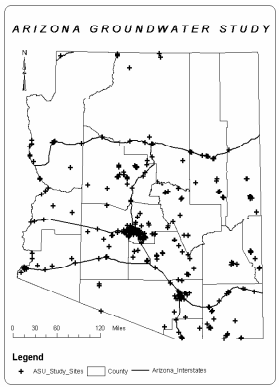
Characterization of the LUST File Analysis

File/Site Selection:

1. Files known to have MTBE data
2. Geographic representation across state
3. Closed files for remediation analysis
4. More "complete" files…



ALL LUSTs in AZ



LUST Files Reviewed

Site selection was not random (e.g., emphasis on gw impact sites vs. "soils-only" sites)

Item 4 likely favors higher population areas vs. rural areas

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File Review

Release Scenario
- depth to GW
- lithology
- site size
- release type
- flow direction
- flow gradient
- water level changes

Charact-erization
- # of Wells (upgradient, downgradient, source zone)
- # of borings
- # of sampling events
- aquifer tests?
- etc.

Impacts
- depth of spill penetration
- source zone size
- soil concentrations
- groundwater concentrations
- trends?
- other chemicals?

Corrective Action
- type of remediation
- duration of remediation
- amount of gasoline removed
- post-remediation data

Extensive QA/QC Procedures → **Database -> Empirical Analysis**

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LUST File Analysis:

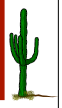
Quick Summary Statistics…

Number of Files Reviewed	Description
324	Files with data suitable for database entry. Nine (9) files/facilities included more than one distinct point of release, providing a total of 335 sites for the database.
2	Groundwater sites ➢ One was a duplicate file for a site already analyzed ➢ One was merged with another site due to source zone and plume characteristics
8	Sites part of the Willcox Area-Wide Investigation o One file was the Willcox Area-Wide master file o Seven files are individual sites part of the area-wide investigation, none of which have enough data for an individual site assessment
46	Data Log Sheets completed but no post-discovery soil or groundwater data available for site
37	File reviewed but no Data Log Sheet filled out o 18 sites with little to no data available o 9 sites with questionable and/or poor data o 3 files too large to perform a reasonable review o 2 files with missing reports o 5 files did not fit criteria of study at the time file was reviewed

A total of 417 files were reviewed

417 files reviewed - 82 files had poor or limited/non-useful data

335 "sites" entered in database (multiple sites at some facilities)



LUST File Analysis:

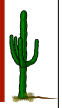
Quick Summary Statistics…

General Site Type	Number of Sites	Acronym	Description
Groundwater Data Available	249	- GW - groundwater	Sites with impacted groundwater, and concentrations exceed Arizona groundwater standards or free-product is present.
	15	- GWU - groundwater undetermined	Sites where available groundwater data shows negligible impact, however, there is reason to suspect more significant impacts. For example, a heavy soils impact is observed at or near the water table, groundwater sampling locations or frequency are insufficient to reasonably demonstrate impact, or minor groundwater impacts are likely associated with off-site source.
	10	- SOV - soils only verified	Sites with impacted soils and sufficient groundwater data to reasonably argue that there is no indication of groundwater impact.
Groundwater Data Not Available	26	- SOU - soils only unverified	Only soils data is available and it suggests that the soils impact does not appear to extend to groundwater.
	34	- SOIL - only soils data available needs further characterization	Only soils data was available and further characterization is needed to determine if groundwater is impacted.
	1	- NA - not analyzed	Site not fully analyzed but was maintained as database entry since site had fractured consolidated sediments.

total number of sites in database – 335

The majority of database entries are groundwater impact sites

Very few sites were classified as "soils only verified" **(an effort was made to locate more files)**



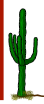
Things to Keep in Mind as We Continue…

A reasonable spatial distribution of sites is represented in the database and a reasonable number of files was reviewed; however -

There may be subtle and not-so-subtle biases in the database as a result of the file selection criteria; in particular:

- The database emphasizes sites with known groundwater impacts
- The database emphasizes sites with more complete data sets

Few "soils-only-verified" sites exist (i.e., conclusions concerning groundwater impacts at soils-only-sites may be based solely on soils data.



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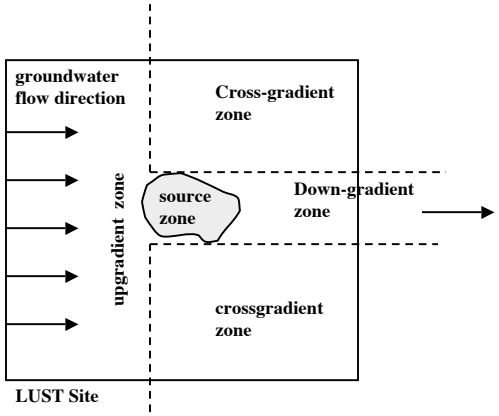
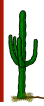
LUST File Analysis:

Characterization of Site Assessment Data…

Independent assessment of groundwater flow direction and its variation based on available data

Independent assessment of "source zone" location and dimensions based on soil boring logs (stains and odors), groundwater data (>1000 ug/L), and soils analysis data





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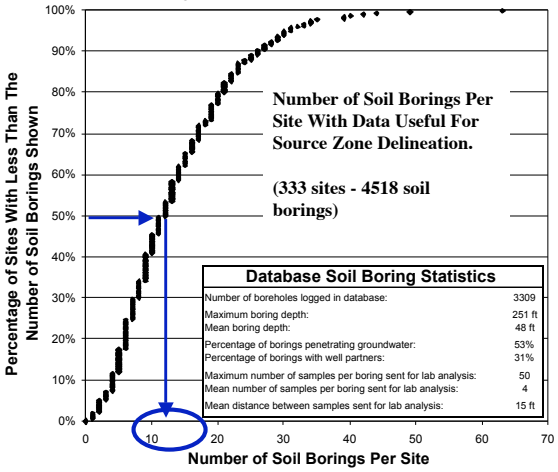
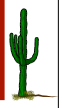
LUST File Analysis:

Characterization of Site Assessment Data…





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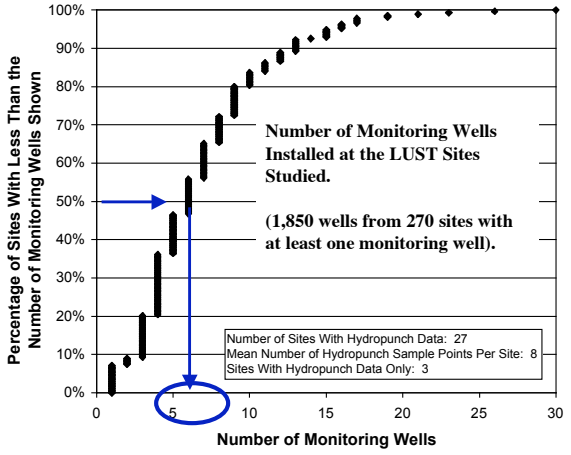
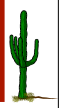
Characterization of Site Assessment Data…





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LUST File Analysis:

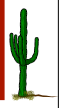
Characterization of Site Assessment Data…

Length of Screened Interval	Number of Monitoring Wells with Screened Intervals of Given Length	Number of Monitoring Wells with Screened Intervals of Given Length and Submergence on at Least One Occasion	Number of Sites with Screen Submergence
<=10 ft.	185	61	
>10 ft. and <=20 ft.	507	73	
>20 ft. and <=30 ft.	611	59	
>30 ft. and <=45 ft.	278	33	
>45 ft. and <=60 ft.	128	15	
>60 ft.	42	1	
Total	1751	242	78

AZ screened intervals tend to be longer than in other states (usually about 15 ft)

This may reflect well costs and uncertainty in long-term rising/falling water levels

This needs to be considered when interpreting data or comparing results from other states studies…



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LUST File Analysis:

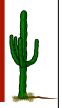
Characterization of Site Assessment Data…

b) Number of Monitoring Wells In, Up-gradient, Down-gradient, or Cross-gradient of the Source Zone.

Criteria	Basis	Percentage of Sites Where the Number of MWs is Less Than or Equal to 0 wells	Percentage of Sites Where the Number of MWs is Less Than or Equal to 1 well	Percentage of Sites Where the Number of MWs is Less Than or Equal to 2 wells	Percentage of Sites Where the Number of MWs is Less Than or Equal to 3 wells	Maximum Number of Wells
Source Zone Monitoring Wells	190 sites 553 source zone wells	6%	37%	54%	74%	17
Up-gradient Monitoring Wells	190 sites 203 up-gradient wells	30%	73%	94%	98%	6
Down-gradient Monitoring Wells	190 sites 239 down-gradient wells	29%	65%	88%	94%	6
Cross-gradient Monitoring Wells	190 sites 467 cross-gradient wells	11%	36%	62%	77%	16
Total Number of Monitoring Wells	1,462 wells at 190 sites with 3+ monitoring wells, known* flow direction, and known* well position					

* known flow direction and well position at sites with sufficient data to confidently determine a dominant flow direction

- **190 sites of about 270 had sufficient wells and data to determine flow direction**
- **65% of those sites had 0 or 1 well classified as "down-gradient"**
- **88% of those sites had 2 or less wells classified as being down-gradient**
- **This may be a reflection of property access issues…**



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LUST File Analysis:

Characterization of Site Assessment Data…

c) Distance to Down-gradient Wells From Source Zone Center or Down-gradient Edge of Source Zone.

Criteria	Basis	Percentage of MWs Where the Distance is Less Than or Equal to 50 ft	Percentage of MWs Where the Distance is Less Than or Equal to 100 ft	Percentage of MWs Where the Distance is Less Than or Equal to 250 ft	Percentage of MWs Where the Distance is Less Than or Equal to 500 ft	Maximum Distance (ft)
Down-gradient of Source Zone Center	238 wells at 190 sites with 3+ monitoring wells and known* flow direction	12%	31%	68%	87%	3,454
Down-gradient of Source Zone Edge	237 wells at 190 sites with 3+ monitoring wells and known* flow direction	32%	53%	81%	92%	3,177

* known flow direction at sites with sufficient data to confidently determine a dominant flow direction

Most wells are placed on the LUST site property or adjacent streets

Little data available for distances >250 ft (assuming that the wells are sampled)

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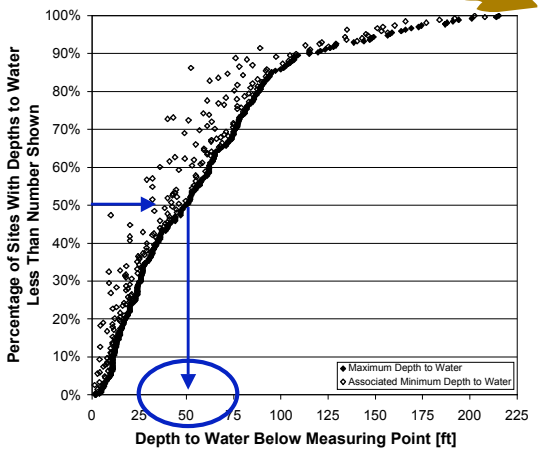
LUST File Analysis:

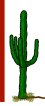
Site Characteristics…

Is this an accurate reflection of AZ LUST site conditions?

-or-

Is this a reflection of a selective/ systematic bias to not install wells at sites with deeper depths to groundwater or to focus efforts on shallower sites?





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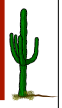
LUST File Analysis:

Site Characteristics…

Zone	Description	Geology	Frequency of Occurrence	Comment
Unsaturated based on 328 sites with known unsaturated zone geology	Unconsolidated Sediments	Interbedded Sands, Silts, Clays	182 (55%)	**Little variation in qualitative geologic descriptions**
		Mixed Sands, Silts, Clays	45 (14%)	
		Sands, Gravels, Cinders	88 (27%)	
		Silts, Clays	13 (4%)	
	Consolidated Materials	Coarse Grained Sedimentary	4 (1%)	33 of 328 sites show consolidated sediments in the unsaturated zone. However, no site shows exclusively consolidated sediments.
		Fine Grained Sedimentary	13 (4%)	
		Igneous, Metamorphic	8 (2%)	
		Limestone	1 (<1%)	
		Volcanic	7 (2%)	
Saturated based on 272 sites with known saturated zone geology	Unconsolidated Sediments	Interbedded Sands, Silts, Clays	126 (45%)	
		Mixed Sands, Silts, Clays	75 (27%)	
		Sands, Gravels, Cinders	52 (18%)	
		Silts, Clays	18 (6%)	
		None Encountered	11 (4%)	
	Consolidated Materials	Coarse Grained Sedimentary	4 (1%)	44 of 282 sites show consolidated sediments in the saturated zone. Only 11 sites show exclusively consolidated sediments.
		Fine Grained Sedimentary	18 (6%)	
		Igneous, Metamorphic	10 (4%)	
		Limestone	0 (0%)	
		Volcanic	12 (4%)	



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LUST File Analysis:

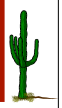
Site Characteristics…

Saturated Zone Geology	Number of Sites	Distribution				
		Hydraulic Conductivity (K)(37 sites with hydraulic conductivity data)				
		Minimum K Value (ft/day)	Percentage of Sites With K Values Greater Than 0.1 ft/day	Percentage of Sites With K Values Greater Than 1 ft/day	Percentage of Sites With K Values Greater Than 10 ft/day	Maximum K Value (ft/day)
IB SSC[1]	4	0.029 ft/day	100%	100%	75%	79 ft/day
Mixed SSC[2]	15	0.006 ft/day	93%	80%	40%	139 ft/day
Sands, Gravels	8	0.051 ft/day	88%	88%	75%	129 ft/day
Silts, Clays	4	0.151 ft/day	100%	50%	25%	100 ft/day
Unconsolidated Sediments and Bedrock[3]	2	0.114 ft/day	100%	100%	0%	4.96 ft/day
Bedrock	4	0.03 ft/day	100%	75%	0%	5.08 ft/day
All Geology	37	0.006 ft/day	95%	81%	43%	139 ft/day

Little aquifer characterization data available

No correlation (except between extreme cases) between qualitative descriptors and hydraulic conductivity (but max values are similar for many soil types…)

Groundwater velocity estimation for risk-based decision-making or NA plans?



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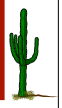
LUST File Analysis:

Site Characteristics…

		Gradient (185 sites with data to determine flow direction and gradient)				
		Minimum Gradient (ft/ft)	Percentage of Sites With Gradients Greater Than 0.003 ft/ft	Percentage of Sites With Gradients Greater Than 0.006 ft/ft	Percentage of Sites With Gradients Greater Than 0.02 ft/ft	Maximum Gradient (ft/ft)
IB SSC[1]	31	0.002 ft/ft	68%	55%	6%	0.40 ft/ft
Mixed SSC[2]	78	0.0005 ft/ft	63%	36%	9%	0.10 ft/ft
Sands, Gravels	43	0.0009 ft/ft	42%	23%	7%	0.04 ft/ft
Silts, Clays	5	0.0005 ft/ft	80%	60%	0%	0.015 ft/ft
Unconsolidated Sediments and Bedrock[3]	19	0.0008 ft/ft	89%	84%	47%	0.40 ft/ft
Bedrock	9	0.015 ft/ft	100%	100%	78%	0.14 ft/ft
All Geology	185	0.0005 ft/ft	64%	45%	15%	0.40 ft/ft

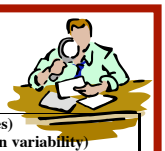
A significant percentage of sites have relatively flat horizontal hydraulic gradients **(changes of <0.3 ft per 100 ft of distance down-gradient)**

No vertical gradient data available



LUST File Analysis:

Site Characteristics…

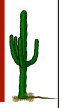


		Range of Flow Direction Variability (degrees) (193 sites with data to determine range of flow direction variability)				
		Minimum Range (degrees)	Percentage of Sites With a Range Greater Than 20°	Percentage of Sites With a Range Greater Than 45°	Percentage of Sites With a Range Greater Than 90°	Maximum Range (degrees)
IB SSC[1]	33	0°	58%	33%	15%	360°
Mixed SSC[2]	84	0°	74%	36%	10%	360°
Sands, Gravels	47	0°	83%	45%	19%	360°
Silts, Clays	5	15°	60%	0%	0%	45°
Unconsolidated Sediments and Bedrock[3]	16	20°	94%	69%	25%	160°
Bedrock	8	0°	75%	38%	0%	60°
All geology	193	0°	75%	39%	13%	360°

1 - IB SSC – Interbedded Sands, Silts, Clays
2 - Mixed SSC – Mixed Sands, Silts, Clays
3 - Includes all geologies where bedrock was encountered beneath unconsolidated sediments, regardless of type.

Most sites have apparent flow direction variations of at least 20 degrees, and a significant percentage of sites have apparent flow direction variations >45 degrees

Is this an accurate reflection of real conditions or a result in errors in groundwater flow direction determination?



More Things to Keep in Mind as We Continue…

The geology at most sites was described qualitatively by a limited number of descriptors (e.g., interbedded sands/silts/clays)

Little quantitative aquifer characterization data is being collected:

- The available data shows no useful correlation between qualitative geology and quantitative properties
- Groundwater velocities needed for risk-based decision-making and NA assessment cannot be defensibly estimated

A significant fraction of sites had insufficient data for flow direction determination

Of those sites with sufficient data, a large fraction had significant "apparent" flow direction variabilities of >20 degrees.

Few wells were classified as "down-gradient" at most sites

Most down-gradient wells are located in close proximity to sites.

LUST File Analysis:

Impacts…

Focus of this "impacts" discussion is on gasoline-release (single or mixed) sites

Release volumes generally unknown - many releases discovered during tank upgrades..

Table 5.6.
Types of Releases at the LUST Sites Reviewed.

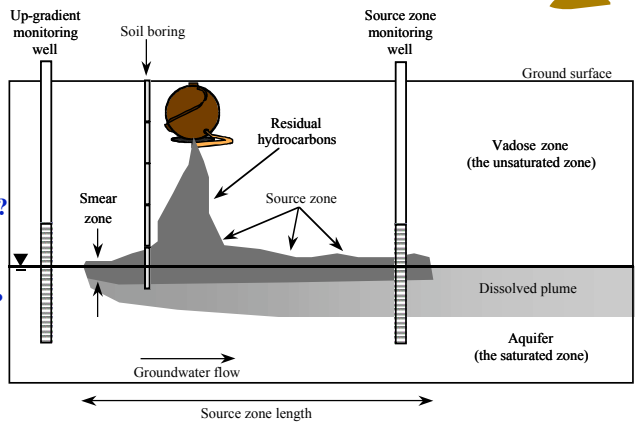
Type of Hydrocarbon Released	Number of Sites
Gasoline	211
Gasoline, Diesel	65
Gasoline, Waste Oil	25
Diesel	17
Gasoline, Diesel, Waste Oil	4
Waste Oil	2
Gasoline, Diesel, Waste Oil, Other (asphalt chemicals)	2
Gasoline, Other (kerosene)	1
Gasoline, Other (petroleum distillates – unspecified)	1
Gasoline, Other (pre-mix oil and gasoline)	1
Gasoline, Diesel, Other (heating oil)	1
Other (aviation fuel)	1
Other (jet fuel)	1
Other (solvents / mineral spirits)	1
Other (unknown)	2

Total number of sites - 335

LUST File Analysis:

Impacts…

- source zone size?
- groundwater concentrations in source zones?
- down-gradient groundwater concentrations?
- correlations?



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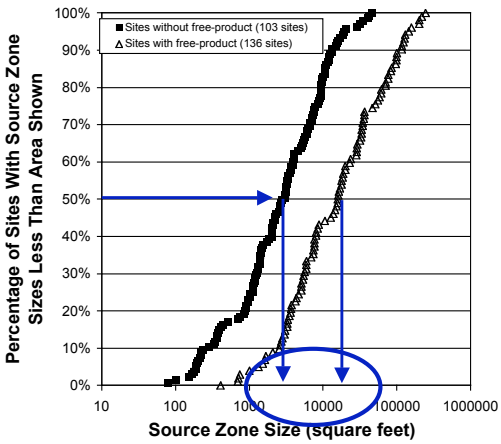
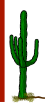
LUST File Analysis:

Impacts - Source Zones…

- In this data set, source zone size <u>did not</u> vary much with:
  - ✓ Qualitative geologic descriptor (same size distribution for all soil types)
  - ✓ Depth to groundwater
  - ✓ Free-product thickness
- Source zones <u>did</u> tend to be larger on average at sites where free-product was observed (but did not depend on free-product thickness..)





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LUST File Analysis:

Impacts…

Chemical Detection and Groundwater Concentration Distributions for Source Zones at Gasoline Contaminated Sites [supplemental sample collection and GC-MS analysis].

	Chemical	Number of Occurrences and Frequency of Detection: Site (30 sites) Number	Site (30 sites) Frequency	Wells (141 wells) Number	Wells (141 wells) Frequency	Concentration in Groundwater (ug/L): 25% of Sites Have Groundwater Concentrations Less Than:	50% of Sites Have Groundwater Concentrations Less Than:	75% of Sites Have Groundwater Concentrations Less Than:	Maximum Concentration	Detectable Concentration
Low	Methanol	0	0%	0	0%	---	---	---	---	500
	Ethanol	1	3%	1	1%	670	670	670	670	100
	Isopropanol	1	3%	1	1%	1,100	1,100	1,100	1,100	100
	n-Propanol	2	7%	2	1%	630	640	660	670	50
	n-Butanol	7	23%	11	8%	250	1,000	6,100	9,600	50
High	MTBE	25	83%	100	71%	91	330	3,800	68,000	1
	TBA	15	50%	36	26%	110	620	2,100	20,000	50
	DIPE	6	20%	13	9%	22	58	610	1,500	1
	ETBE	2	7%	2	1%	16	51	46	61	1
	Benzene	30	100%	137	97%	160	1,500	8,600	120,000	0.5
	Toluene	30	100%	131	93%	29	310	6,500	110,000	0.5
	Ethylbenzene	29	97%	127	90%	76	1,100	3,700	96,000	0.5
	M/p-Xylene	30	100%	135	96%	52	1,100	4,900	73,000	0.5
	o-Xylene	29	97%	124	88%	29	440	4,400	98,000	0.5
	1,3,5-TMB	30	100%	131	93%	12	470	1,300	27,000	0.5
	1,2,4-TMB	30	100%	130	92%	65	1,400	3,500	170,000	0.5
	1,2,3-TMB	30	100%	129	91%	22	470	1,000	58,000	0.5
	Naphthalene	30	100%	131	93%	28	320	1,100	63,000	0.5

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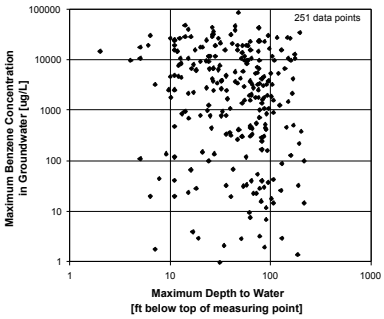
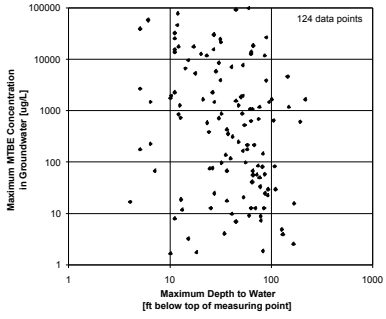
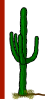
LUST File Analysis:

Impacts - Source Zones…





No correlation observed between groundwater concentrations and depth to groundwater…



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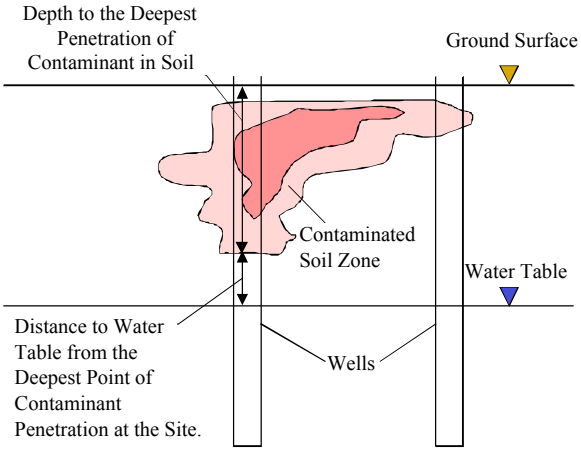
LUST File Analysis:

Impacts - Source Zones…



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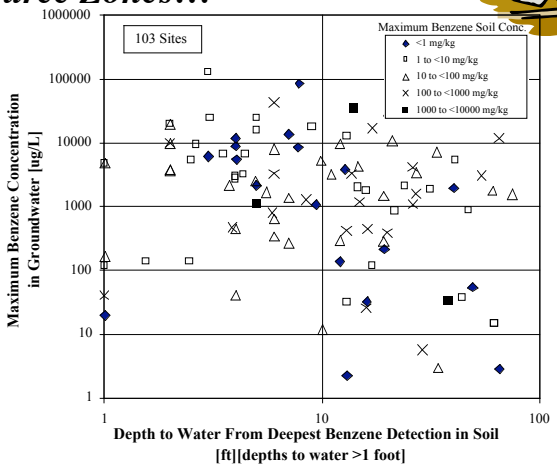
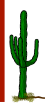
LUST File Analysis:

Impacts - Source Zones…

No correlation observed between groundwater concentrations and depth to groundwater from deepest measured soil impact or with geology…





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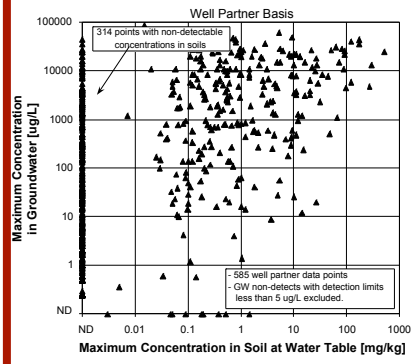
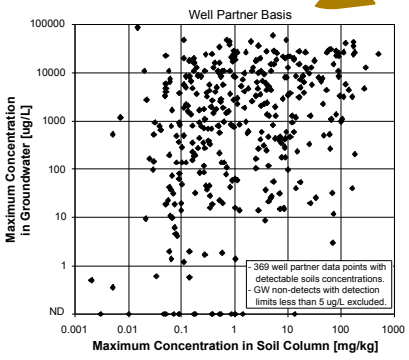
LUST File Analysis:

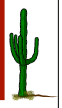
Impacts - Source Zones…





No correlation observed between groundwater concentrations and soil concentrations (for any combination of data)…

GW Impacts at high fraction of sites with non-detect in soils at water table



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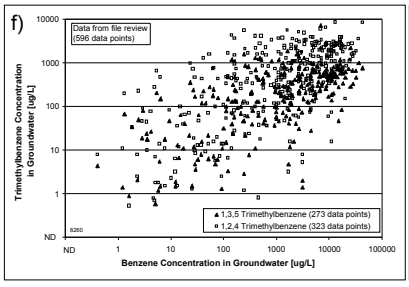
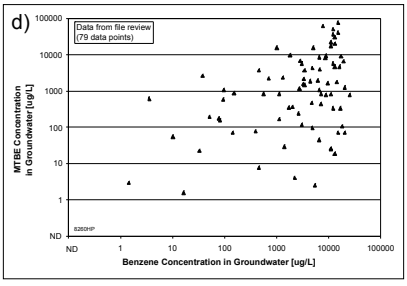
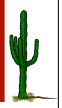
LUST File Analysis:

Impacts - Source Zones…





Dissolved source zone concentrations of all chemicals generally increased as the benzene concentration increased, but with a large degree of scatter about this trend.



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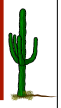
Some More Things to Keep in Mind as We Continue…

With respect to source zone impacts:

- ✓ **Conventional wisdom is not supported by this data (impacts seem not affected by depth to water, separation between soil impacts and groundwater, soil concentrations, or geology…)**
- ✓ **Source zones are generally 2,000 - 20,000 ft²**
- ✓ **Chemicals typically present included BTEX, MTBE, TBA, Napthalene, TMB's**
- ✓ **Alcohols (other than TBA) not detected often**
- ✓ **Concentration ranges for chemicals present often in the 1,000 - 10,000 ug/L range (MTBE less than benzene?)**
- ✓ **Correlations - only between chemical concentrations…**



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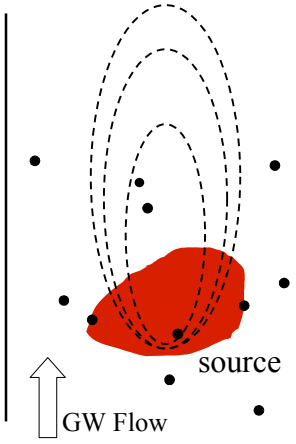
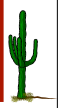
Down-Gradient Impacts..

What's Different About this Study In comparison with the CA and TX LUST studies?

A "data-driven" approach is being used and the focus is not on quantification of "plume lengths" through modeling.

The data do not support the modeling type approach used in other studies…





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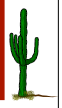
ASU

LUST File Analysis:

Impacts Down-gradient…

Down-gradient Distance From UST System Center[1]	Number of Sites With Wells in Distance Range	Number of Wells in Distance Range for Which Lab Data is Available	Distribution: Number of Wells for Distance Range (Percentage of Wells for Distance Range) for Which the Concentration in Groundwater Exceeded the Value Shown[2]			Maximum Concentration for Range
			Benzene Concentration in Groundwater			
			10 ug/L	100 ug/L	1,000 ug/L	Maximum
0-100 ft	98	360	297 (83%)	255 (71%)	170 (47%)	47,000 ug/L
101-200 ft	47	113	71 (63%)	55 (49%)	35 (31%)	49,000 ug/L
201-300 ft	24	61	34 (56%)	29 (48%)	27 (44%)	28,000 ug/L
301-400 ft	8	48	27 (56%)	19 (40%)	10 (21%)	18,000 ug/L
401-600 ft	8	22	10 (45%)	8 (36%)	3 (14%)	27,000 ug/L
601-800 ft	8	9	4 (44%)	2 (22%)	1 (11%)	1,100 ug/L
801-1,000 ft	3	6	2 (33%)	0 (0%)	0 (0%)	28 ug/L
> 1,000 ft	3	12	3 (25%)	0 (0%)	0 (0%)	45 ug/L

There are differences between results referenced to "source zone center" and to the "edge of source zone"…(both are presented in report)



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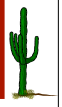
LUST File Analysis:

Impacts Down-gradient…

			MTBE Concentration in Groundwater			
			10 ug/L	100 ug/L	1,000 ug/L	Maximum
0-100 ft	98	134	90 (67%)	60 (45%)	28 (21%)	100,000 ug/L
101-200 ft	47	44	24 (55%)	17 (39%)	6 (14%)	80,000 ug/L
201-300 ft	24	25	16 (64%)	9 (36%)	8 (32%)	31,000 ug/L
301-400 ft	8	19	10 (53%)	7 (37%)	3 (16%)	14,000 ug/L
401-600 ft	8	12	6 (50%)	3 (25%)	1 (8%)	1,300 ug/L
601-800 ft	8	3	0 (0%)	0 (0%)	0 (0%)	5 ug/L
801-1,000 ft	3	3	1 (33%)	0 (0%)	0 (0%)	44 ug/L
> 1,000 ft	3	7	3 (43%)	2 (29%)	0 (0%)	160 ug/L

Not much discernible difference between benzene and MTBE impacts from broader database analysis…

Low confidence in conclusions drawn for distances beyond 300 ft because of lack of data and….



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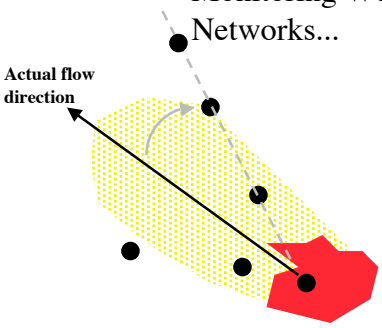
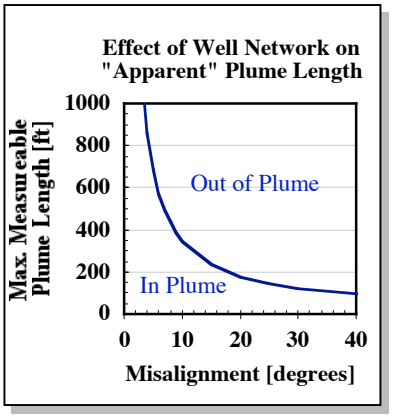
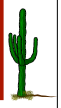
A Technical Consideration...

Dissolved Plume Characterization Monitoring Well Networks...







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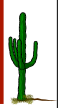
Temporal Trends?

No obvious ones - This is different from conclusions from other studies..

Trend for Water Level (WL) and/or Groundwater Concentration (GW Conc.)	Distribution - Number of Sites With Discernible Water Level and/or Pre-remediation Groundwater Concentration Trends	
	Sites with long-term water level trends (270 sites with at least one monitor well)	
	Number of Sites	The fluctuation at any given site fell within the following range
Rising WL	7	8 to 25 feet
Falling WL	18	1 to 27 feet
Seasonal WL fluctuation	12	3 to 20 feet
No WL trend	233	---
	Sites with at least one well with long-term pre-remediation groundwater concentration trends	
	Benzene (268 sites)	MTBE (181 sites)
Rising GW Conc.	2	2
Falling GW Conc.	46	3
No GW Conc. trend	222	176
	Sites with at least one well with long-term pre-remediation groundwater concentration trends and long-term water level trends	
	Benzene (268 sites)	MTBE (181 sites)
Rising WL and Falling GW Conc.	3	0
Rising WL and Rising GW Conc.	0	0
Falling WL and Falling GW Conc.	5	0
Falling WL and Rising GW Conc.	0	0
Rising/Falling WL and No GW Conc. trend	17	16
Rising/Falling GW Conc. and No WL trend	35	5



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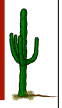
Site "Snapshots"…

ADEQ Facility ID	Number of Borings	Total Feet Drilled	Type of Drilling	# GW Samples Collected from Borings	# GW Samples From Monitor Wells	Total # of GW Samples Collected	Relevant Field Comments
2072	7	322	Auger	7	16	23	Continuous core not possible - Split spoon sampling on 1 foot intervals near water table.
1301	15	527	GeoProbe	15	10	25	Continuous core collected in 1 borehole.
1254	9	272	Auger	9	13	22	Continuous core not possible - Split spoon sampling on 1 foot intervals near water table.
1224	7	234	Auger	11	10	21	Continuous core collected in 1 borehole. Vertical groundwater sample investigations attempted/performed at 3 locations.
1329	15	362	GeoProbe	26	6	32	Continuous cores collected in 2 boreholes. Vertical groundwater sample investigations performed at 7 sample locations.
1491	24	376	GeoProbe	28	10	38	Continuous core collected in 1 borehole. Vertical groundwater sample investigations performed at 4 sample locations.

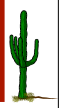


Site "Snapshots"…

Comments – Extent of Dissolved Contamination
Facility 2072 - Plume running southeast with free-product at 300 ft from UST system and benzene concentrations of 3403 ug/L present at 500 ft. Contamination within 250 ft of UST system appears to be broadly disseminated. Unable to track main axis of plume beyond 550 ft of UST system due to utility clearance; however, monitoring wells show benzene extending to at least 850 ft (246 ug/L).
Facility 1301 - Contaminant concentrations found along northeastern border of property over 100 ft from UST system (2,220 ug/L benzene and 2,150 ug/L MTBE) - Access prevented full delineation of source zone area. Low MTBE concentrations (6 – 17 ug/L) detected up to 450 ft in the northeasterly direction. Possible 2nd unrelated source of contamination detected at 500 ft east of site based on strong odors from groundwater samples. Drilling permit restricted further investigation of this source zone.
Facility 1254 - Plume extending over 550 ft from UST system. Heavy impact noted at 250 ft (2,200 ug/L benzene, 370 ug/L MTBE) with diminishing concentrations at 550 ft (260 ug/L benzene, 298 ug/L MTBE). It appears that there is little to no attenuation of MTBE between the source and 550 ft down-gradient. Unable to track plume further due to budget and time constraints.
Facility 1224 - Down-gradient direction is not well defined for site. Impacts observed at 125 ft from the UST system (86 ug/L MTBE), including MTBE to SW. Unrelated 2nd source also discovered within 120 ft of UST system and could be responsible for impacts noted in facility MWs in that direction. Signature of contaminant in that area suggests very weathered product.
Facility 1329 - MTBE detected at 184 ug/L 90 ft to the south of the UST system. 143 ug/L TBA and low levels of n-butanol, naphthalene, and MTBE were detected at 290 ft to the southwest. Unable to track contaminant due to access and utility clearance.
Facility 1491 - Concentrations exceeding 1,000 ug/L extend over 150 ft from the UST System in south and southwesterly directions. MTBE detections extend to the south and southwest up to 375 ft. Attempts to track main axis of plume constrained by access. Investigations 700 ft from UST system showed no detectable concentrations, although investigations were not in a direct line with more proximal impacts.

"Before" and "After" site conceptual models are different for most sites…

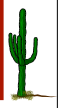
MTBE plumes attenuate more slowly than suggested by broad data base analysis



Some More Things to Keep in Mind as We Continue…

With respect to down-gradient groundwater impacts:

- ✓ **Very few data points available beyond 200 - 300 ft down-gradient, and given flow direction "variability" and typical source sizes, the confidence in conclusions is therefore low.**
- ✓ **Data clearly inappropriate for modeling of plume "lengths"**
- ✓ **Not much apparent difference between BTEX and MTBE behavior in broader data set analysis, but it is clear from individual site characterization that MTBE attenuates less with distance than BTEX…**
- ✓ **No clear temporal trends in dissolved concentration at most sites…**



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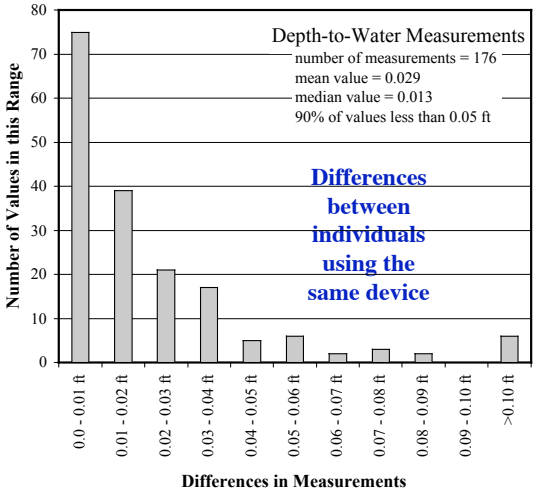
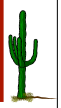
Flow Direction Assessment:

Water Level Elevation Measurement Errors…





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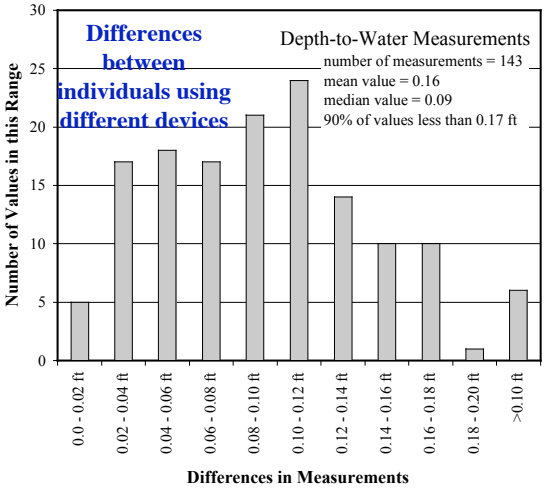
Flow Direction Assessment:

Water Level Elevation Measurement Errors…



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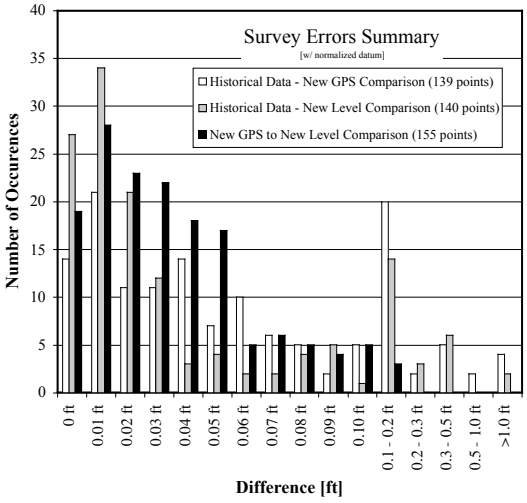
Flow Direction Assessment:

Survey Measurement Errors…

Top-of-Casing Elevation Survey Error Assessment Results for Data Sets Re-referenced to a Common Survey Point.



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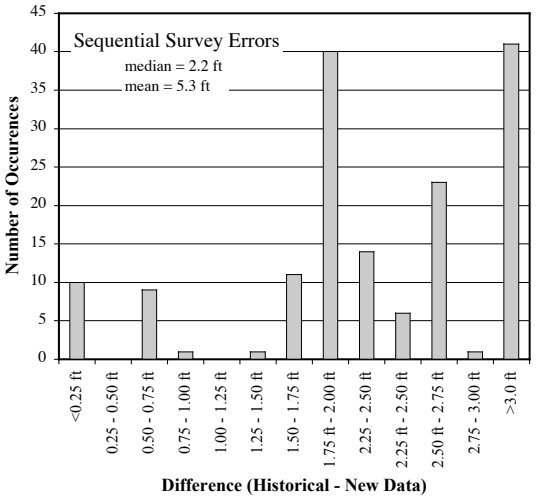
Flow Direction Assessment:

Survey Measurement Errors…

Top-of-Casing Elevation Survey Error Assessment Results for Data Sets Not Re-referenced to a Common Survey Point.



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Some More Things to Keep in Mind as We Continue…

With respect to groundwater flow direction errors:

- ✓ **Individual measurements likely good to within 0.02 ft; but larger deviations are possible.**
- ✓ **Introducing a second instrument could add more significant error (0.2 ft in this one-time study)**
- ✓ **Surveys are likely accurate to within similar error as individual water level measurements (<0.05 ft in most cases)**
- ✓ **Sequential surveys have the potential to introduce the largest errors in the process (>1 ft in many cases)**
- ✓ **What is a "significant error"? - >0.1 ft? More analysis is needed…**

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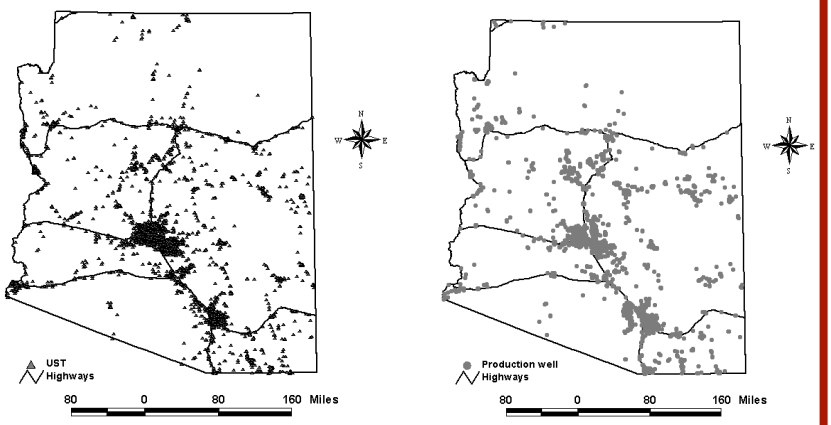
GIS Analysis - Relative Locations…

Figure 8.1. Spatial distribution of UST sites and production wells (municipal or utility) in Arizona.



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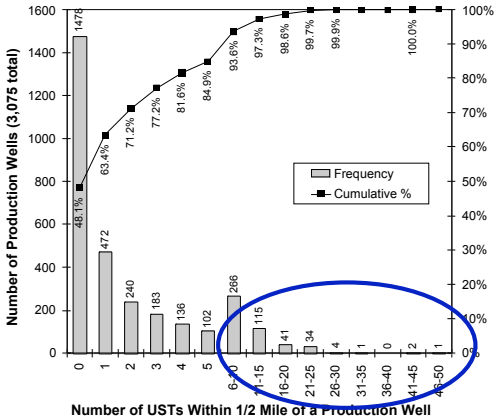
GIS Analysis…

Municipal supply wells

Resolution limited to 1/2 mile for this data set

Report suggests that wells having >10 USTs in vicinity may be most vulnerable to impacts

Figure 8.2. Histogram of Number of Production Wells Having the Specified Numbers of UST Sites Located Within One-Half Mile. The Total Number of Wells in this Analysis was 3075.



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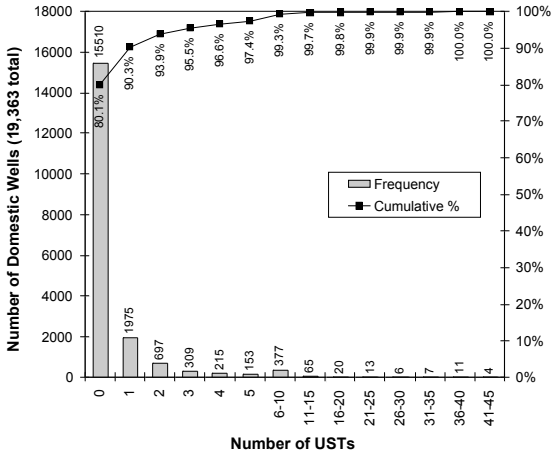
GIS Analysis…

Residential supply wells in Yavapai County

Resolution limited to 1/2 mile for this data set

Report suggests a single UST can adversely impact a residential well, but the relative position is critical



Some More Things to Keep in Mind as We Continue…

With respect to assessing impacts to wells:

- ✓ **Resolution of current data set is limited (1/2 mile)**
- ✓ **The concentration vs. distance data from this study is limited beyond 200 - 300 ft.**
- ✓ **Therefore, any spatial-based capture-zone type analysis will be very coarse and conservative until the spatial resolution can be increased and our understanding of concentrations at large distance increases.**

Remediation Analysis..

The goal was to assess remediation system performance and costs in different settings; however:

- ✓ The available data was just too limited
- ✓ Very little pre- and post-remediation data of any significance
- ✓ Very little performance data of any significance
- ✓ Data interpretation and quality was highly questionable…
  - Collecting samples during active remediation (from IAS and ORC wells)
  - Too short of a post-remediation time period to assess results
  - Changes in wells being monitored (some become damaged…)

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Remediation Analysis…

Little active- and no post- remediation data
Diesel site – Low BTEX concentrations
BTEX concentrations still high – No apparent response
Site closed based on samples collected during in situ air sparging
Other technologies used in conjunction with or prior to NA
Wells submerged – groundwater quality not known
ORC utilized – Unknown response from NA
Concentration reductions related to falling groundwater level
Active remediation data showed little change - No post-remediation data
Diesel site – very low BTEX concentrations
Only 1 pre-remediation event and post-remediation data from different wells
No discernible change in groundwater quality - Concentrations too low
No discernible response
Only 1 pre-remediation event and post-remediation data from different wells
Used in conjunction with or followed by other technologies
Some attenuation noted but remediation stopped
Free-product appears in numerous wells during/after treatment
No distinct change in wells with consistently detectable concentrations and sampling of well with highest concentration was discontinued
Improper screened interval and no clear remedial response
Unknown start date – Possible use in conjunction with AS/SVE
Only 1 pre-remediation event and post-remediation data from different wells
Unknown stop date – Possible sampling at same time of treatment
Diesel site – Low BTEX concentrations
Some attenuation noted but samples were collected during treatment
No discernible change in groundwater quality

Insufficient Data……

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